Key parameters to estimate the clear-sky OLR over tropical regions: Simple models and their evaluation

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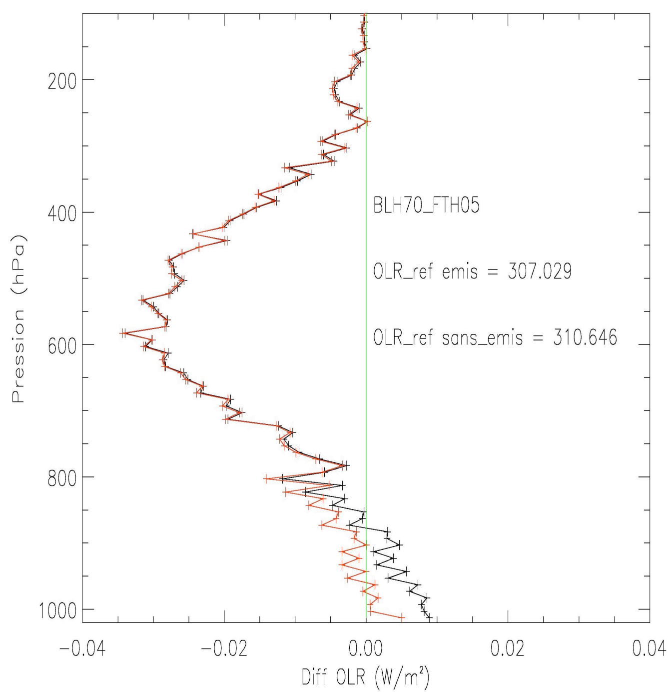

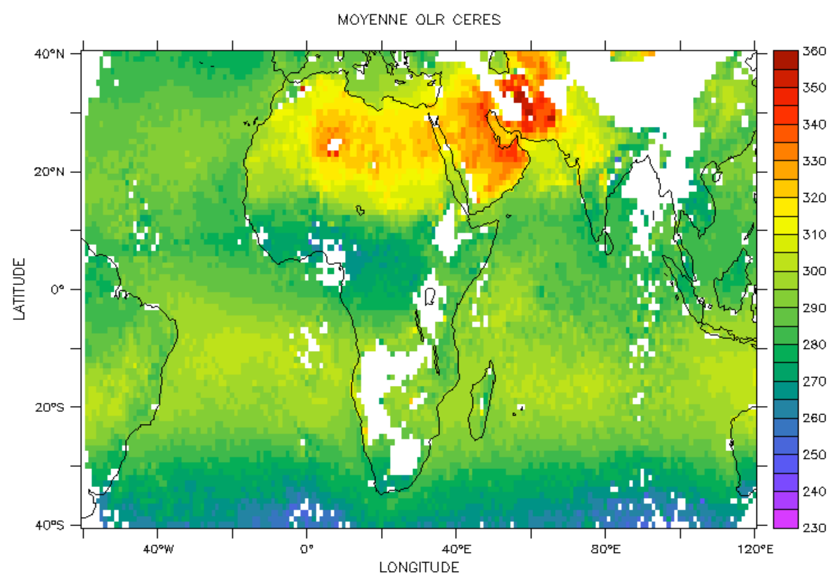

OLR

Outline

I – Introduction

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- I.2 Motivation

II – Radiative transfer tool : Modtran

- II.1 – Idealized atmospheres, starting assumptions
- II.2 – Surface emissivity impacts over the IR radiation

III – Statistical approach : Satellite data

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- III.2 – Multi-linear regression

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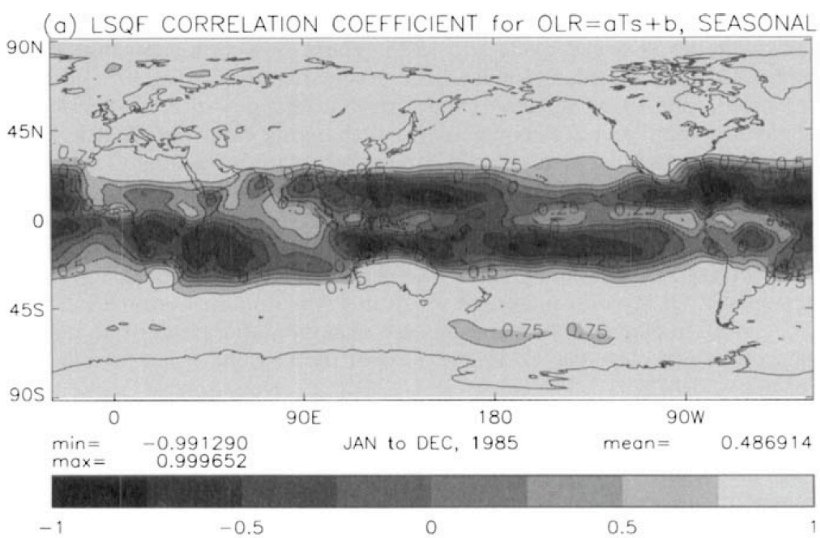
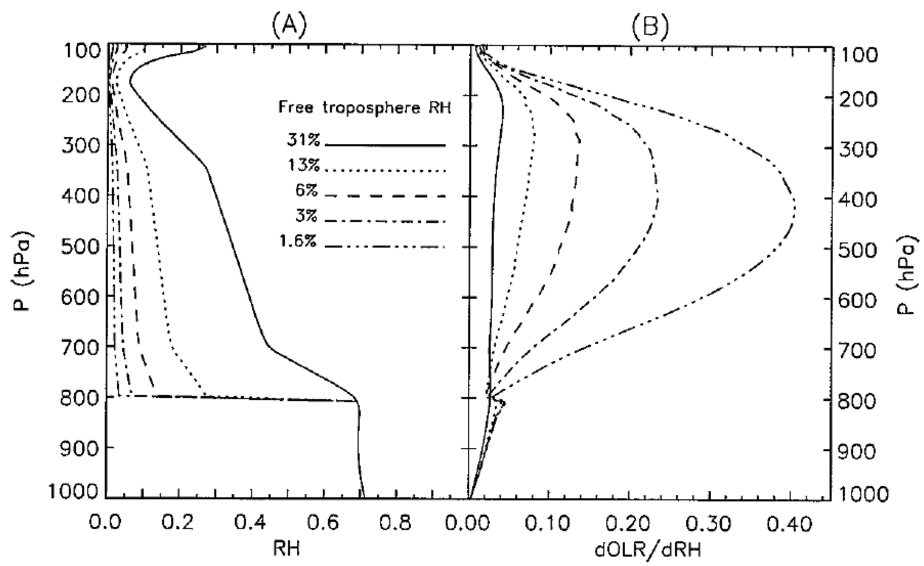
Introduction (1/3)

I.1 – State of the art

- Infrared (IR) Outgoing Longwave Radiation (OLR) is strongly correlated to Surface Temperature (Ts) over the whole globe (*Allan et al.1999*).

- In the tropical regions, moist plays a major role on OLR as well, particularly on its variability (*Buehler et al.2004*). OLR is mainly sensitive to the mid-upper tropospheric humidity (*Spencer et Braswell 1997*, *Allan et al. 1999*).



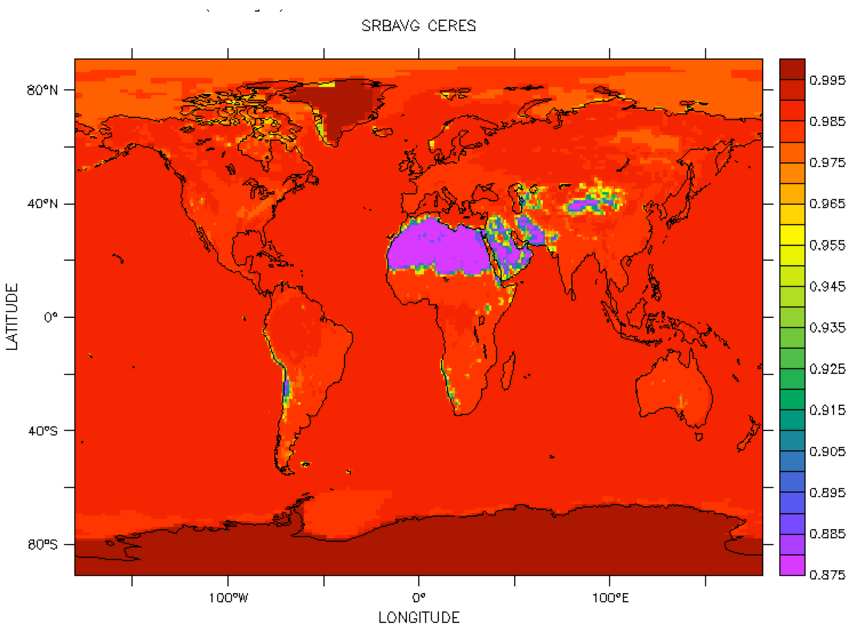


Introduction (2/3)

I.1 – State of the art

- In the tropics there are surfaces with low emissivities in the IR (~0.85), mainly the deserts, and that are not accurately estimated (*Zhang et al.2007*).

- Evaluate if the blackbody emissivity approximation can yield systematic errors that should be taken into account for the IR radiation estimates.



Window emissivity

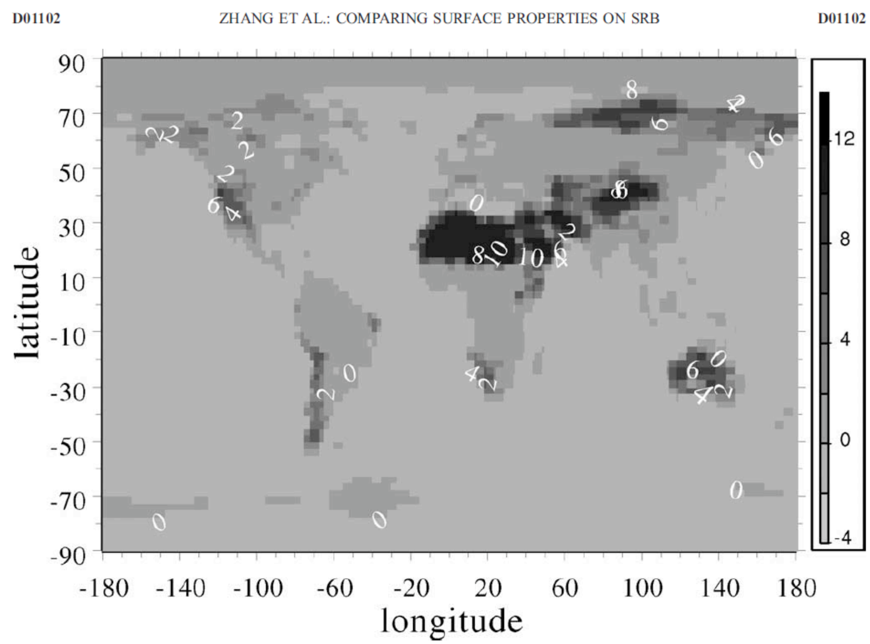


Figure 7. Global map of differences (ISCCP-FD minus SRB) of window region emissivities (in %) from ISCCP-FD 1992 annual mean and SRB climatology.

Introduction (3/3)

I.2 – Motivation

Clear-sky greenhouse effect

$$Ga = LW_{S\uparrow} - OLR$$

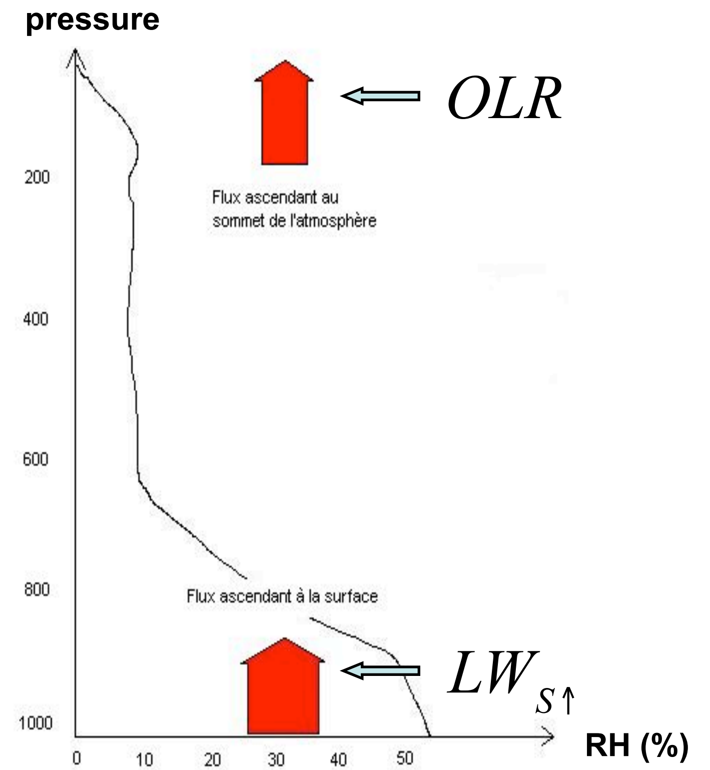
- To understand and estimate the clear-sky greenhouse effect over the tropics

- Create a simple model of Ga to evaluate the impact of different kind of changes on the key variables of Ga or OLR.

<u>Two complementary ways to achieve that :</u>

- Idealized study cases with the Modtran model

- Statistical approach with satellite data



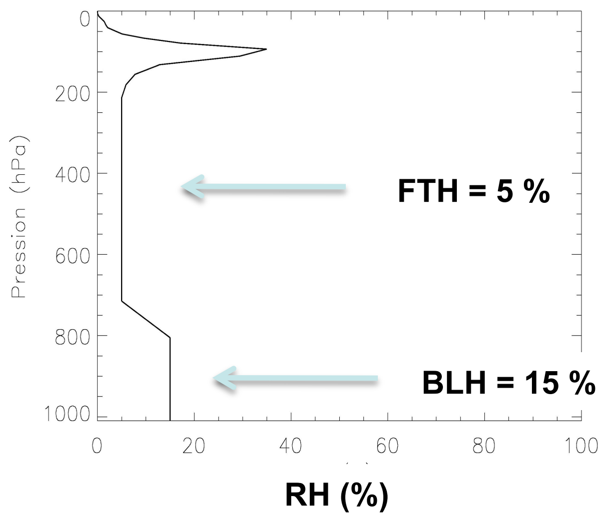
Modtran (1/3)

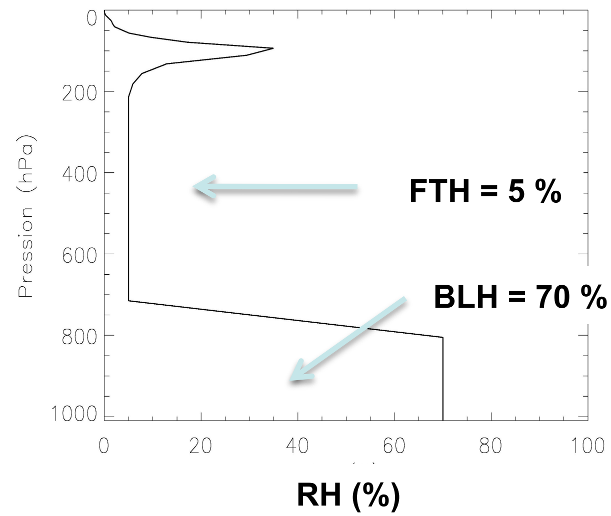
II.1 – Idealized atmospheres, starting assumptions

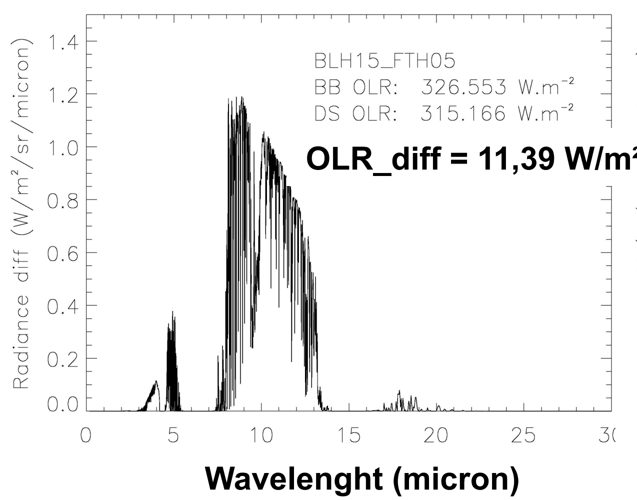
- Two humidity layers : the Boundary Layer (BL) and the Free Troposphere (FT) layer.

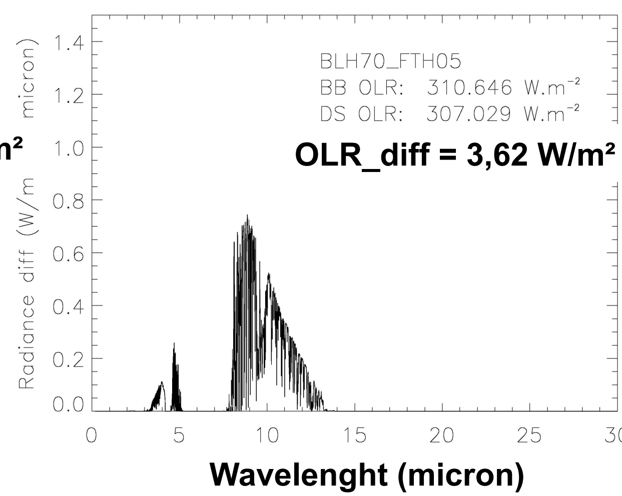
- All other atmospherical parameters are from the McClatchey tropical standard profile (*McClatchey et al.1971*)

- There is a 3% difference in the OLR (11 W/m²) for the driest atmosphere.









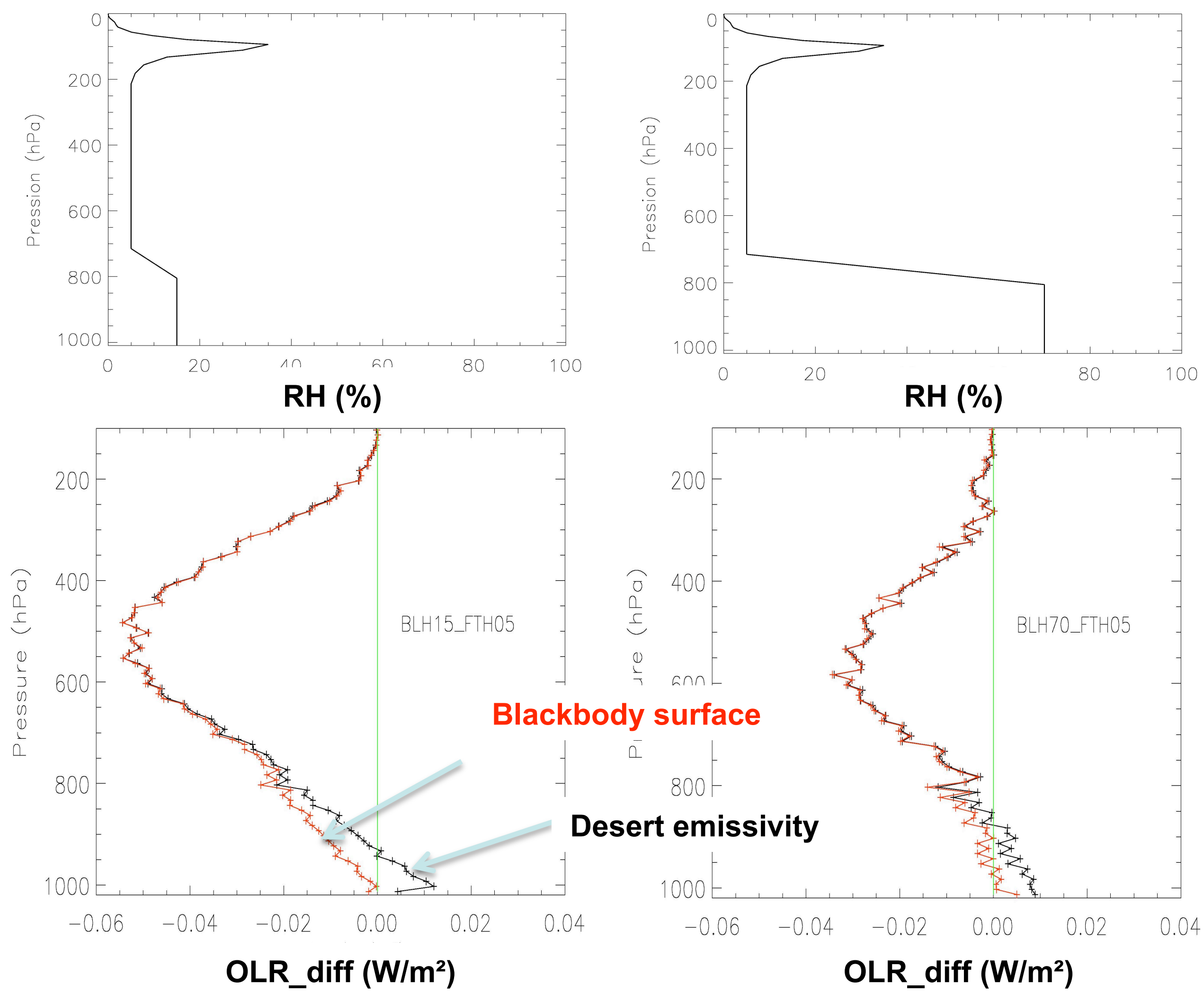
Modtran (2/3)

II.2 – Surface emissivity impacts over the IR radiation

OLR jacobians with respect to RH for the two types of surfaces

+1% perturbations in RH over 10 hPa thick layers

Differences between the two surfaces appear in the lower part of the atmosphere



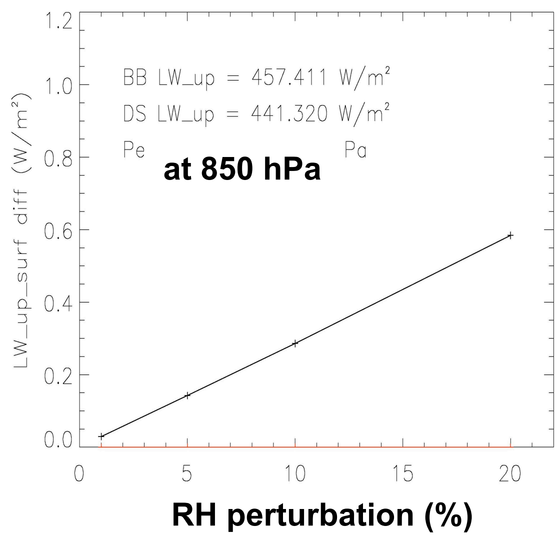
Modtran (3/3)

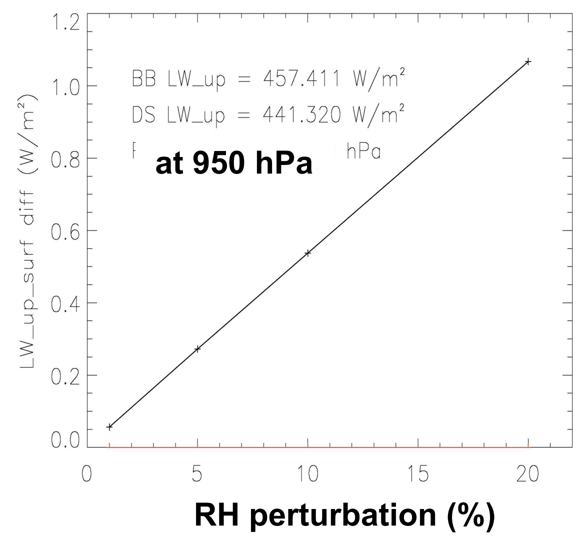
II.2 – Surface emissivity impacts over the IR radiation

For desert-like surfaces :

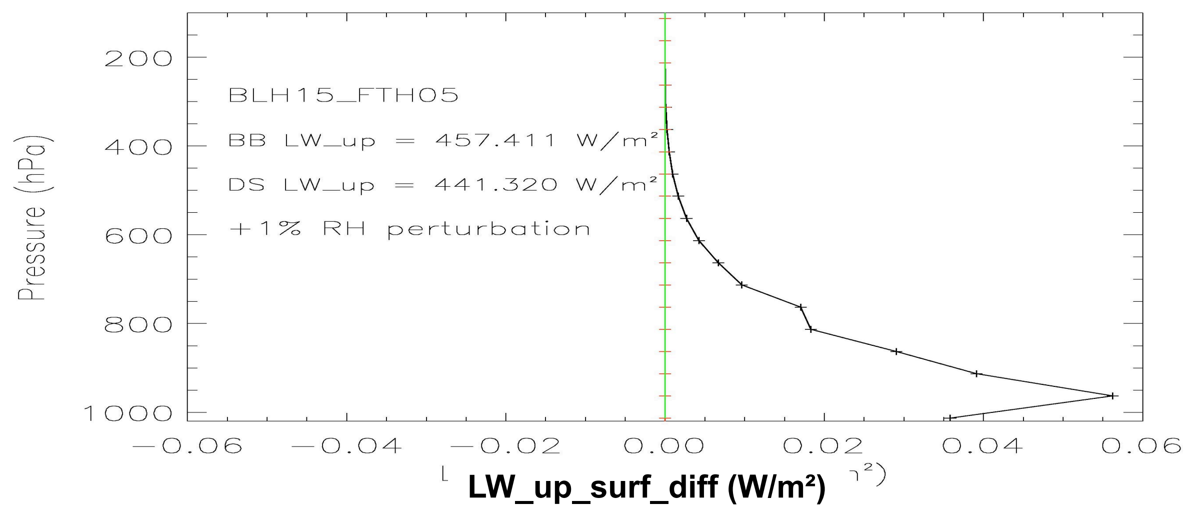
- Linear increase of the surface upward IR flux for greater RH perturbations

- The slope gets bigger if the perturbed layer gets closer to the surface





- We plot the LW_up surface flux jacobian with respect to RH perturbations



Satellite data (1/6)

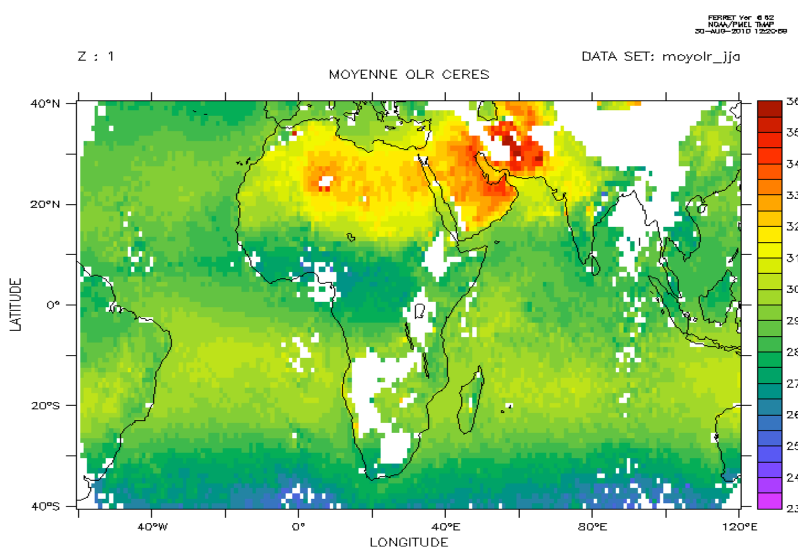
III.1 – Available data sets

- **CERES SSF** – 07/2002-06/2003 (AQUA)

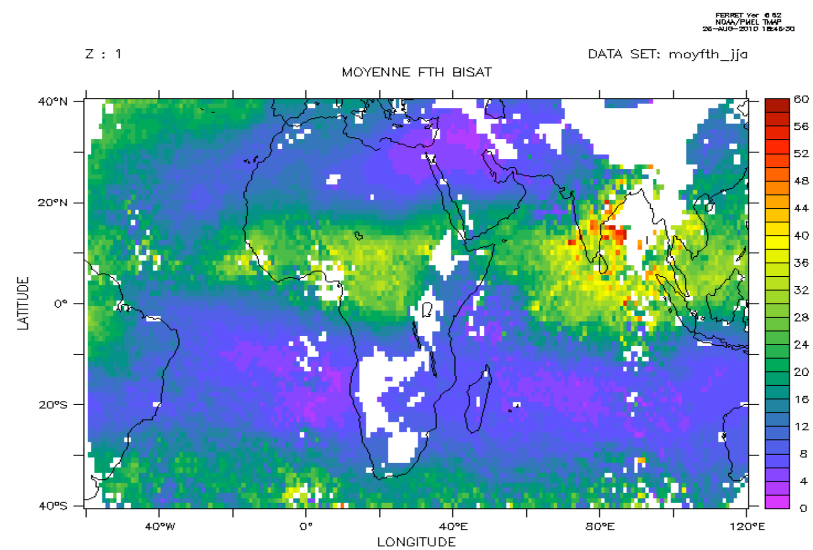
We take from this data sets the following products : **OLR** and **Ts**

- **FTH BISAT** – 2000-2005 (2 x METEOSAT)

FTH estimate, every 3 hours, over the bisat region (60°W-120°E , 40°S-40°N) (water vapour band product, METEOSAT (*Brogniez et al.2006*))



OLR



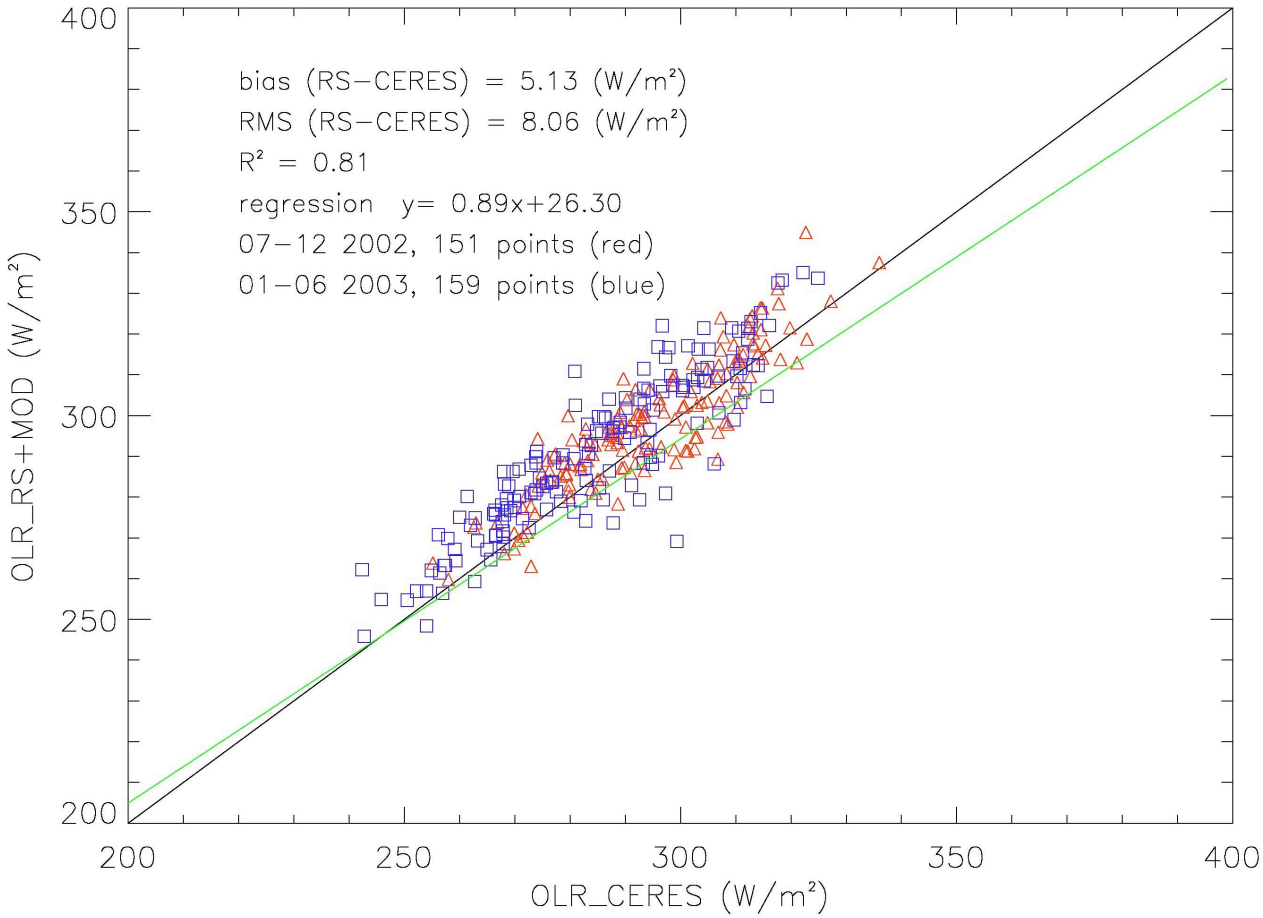
FTH

Satellite data (2/6)

III.1 – Available data sets

<u>Night OLR data</u>

We plot the OLR computed by Modtran with radiosonde humidity profiles vs CERES OLR (space time coincidence : 1°*1°, two hours time bin).



The « best » OLR estimate, vertically and spectrally resolved

Satellite data (3/6)

III.2 – Multi-linear regression

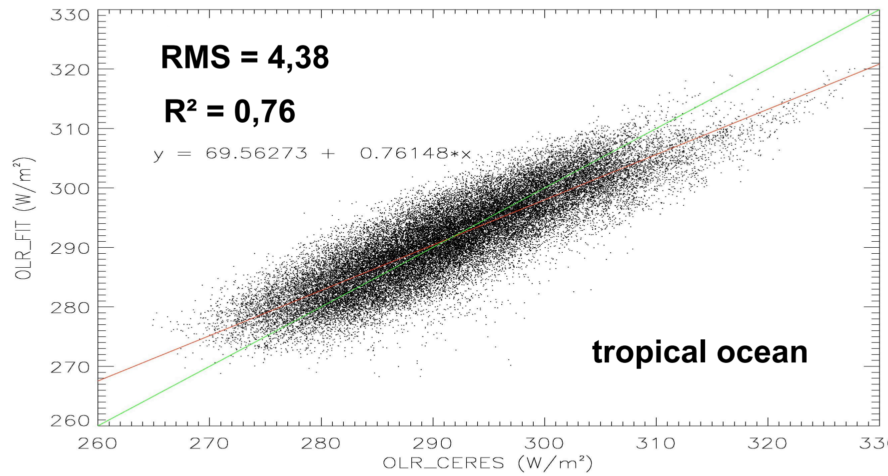
We focus on the JJA season, 25°S-35°N and night measurements of OLR

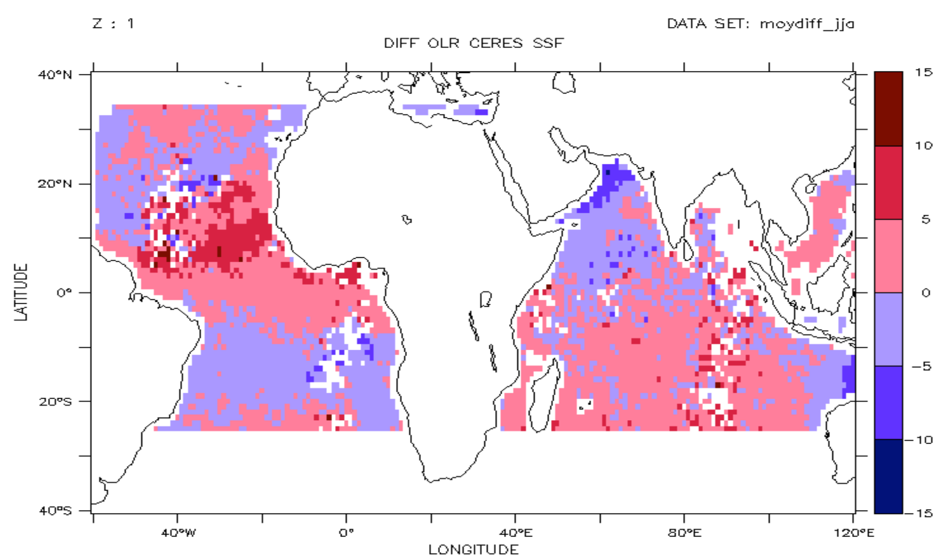
We fit the OLR with the following model:

$$OLR = a \cdot \sigma \cdot T_S^{\,4} + b \cdot \ln(FTH) + c$$

Ocean fit vs data (top)

Mean of the difference between the fit and the data (bottom)

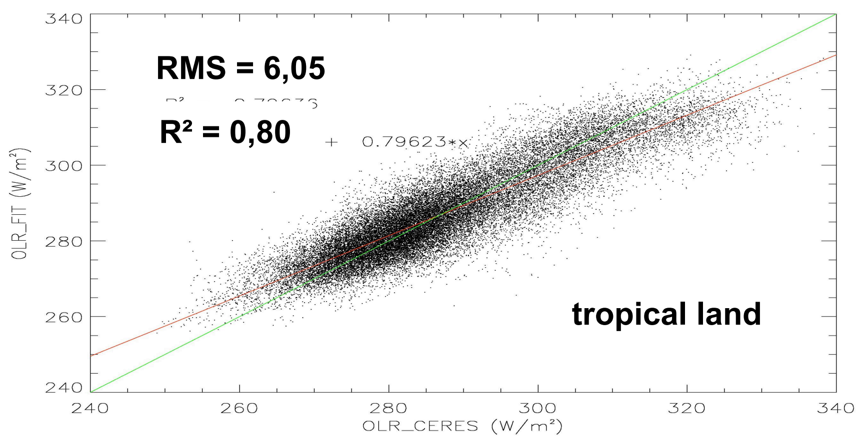


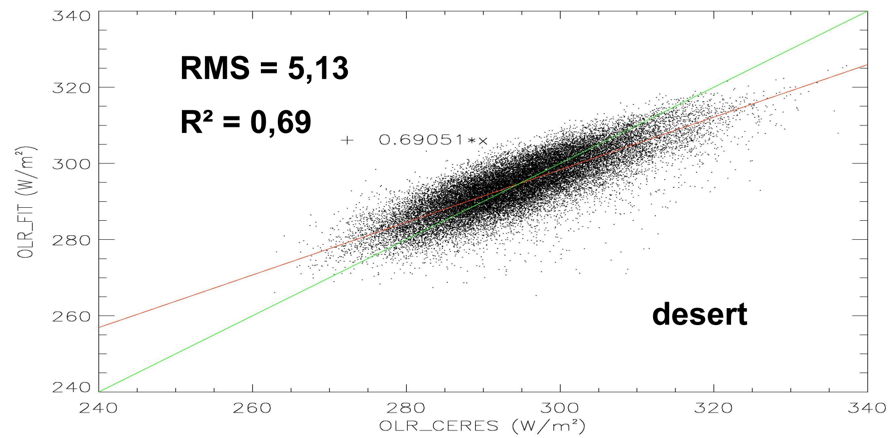


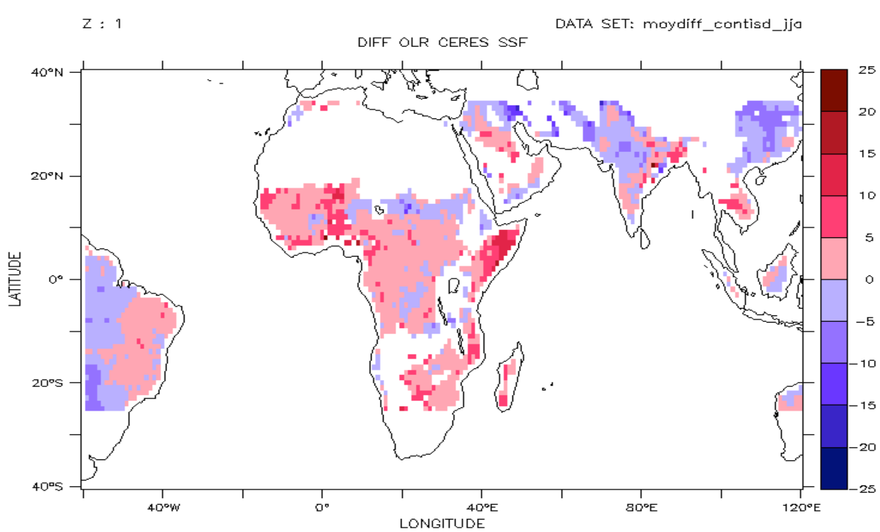
mean OLR_diff (W/m²)

Satellite data (4/6)

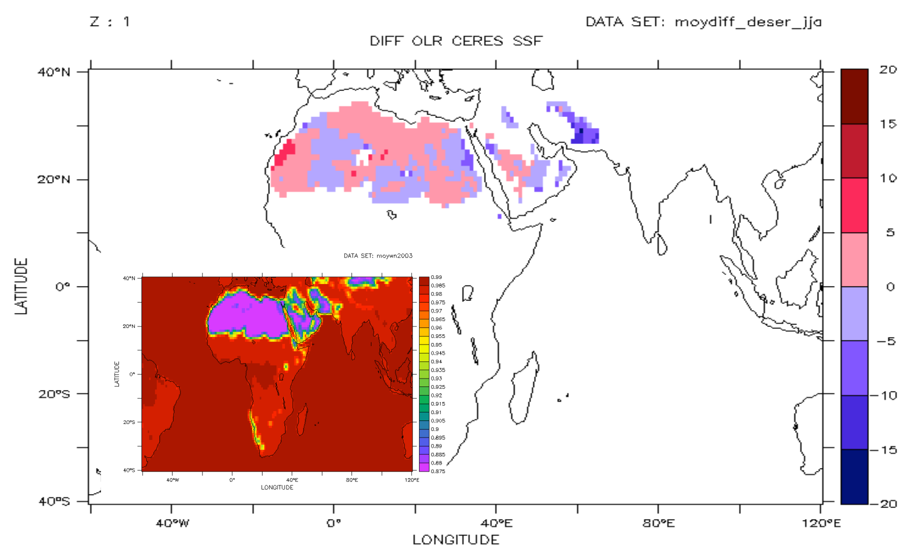
III.2 – Multi-linear regression







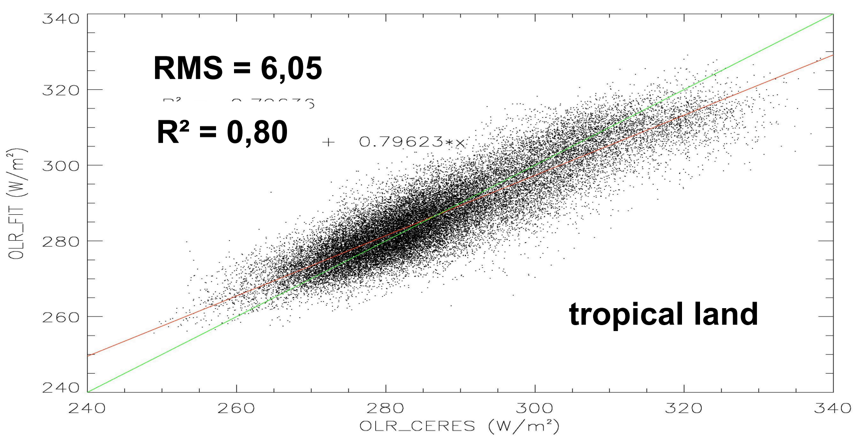
mean OLR_diff (W/m²)

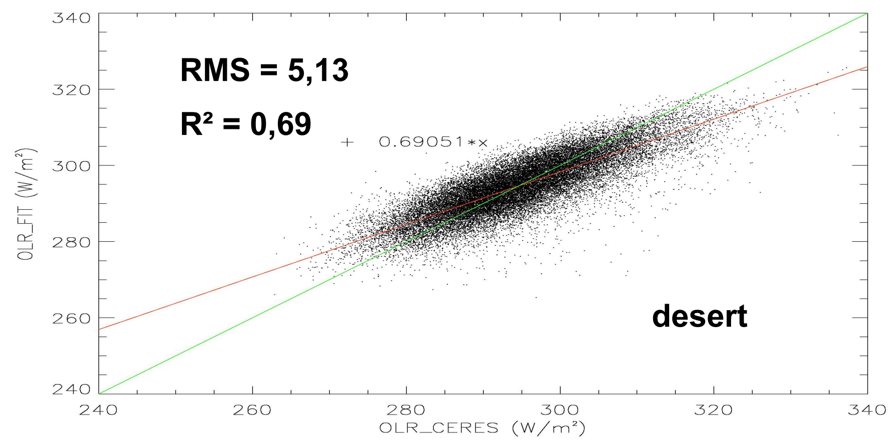


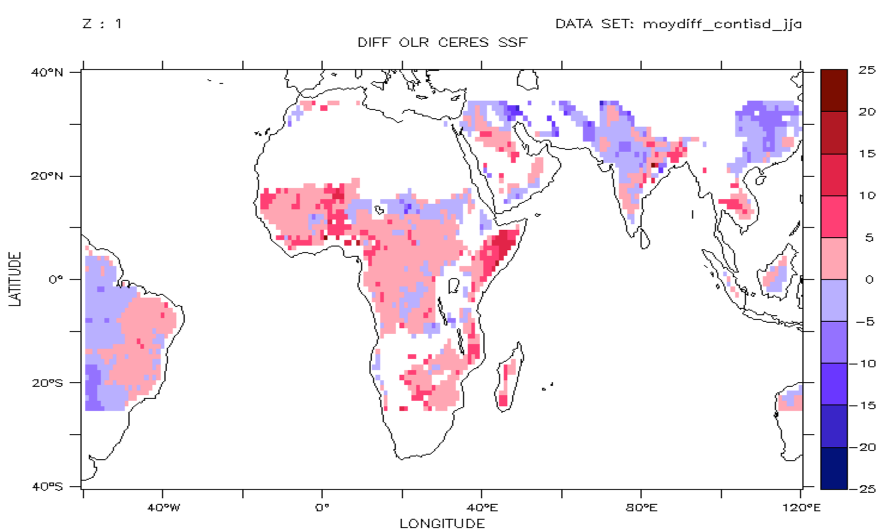
mean OLR_diff (W/m²)

Satellite data (4/6)

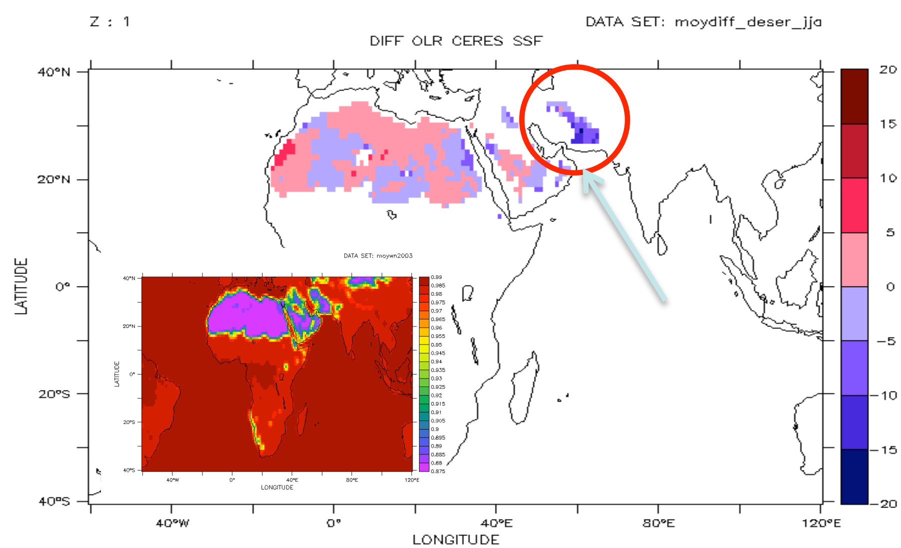
III.2 – Multi-linear regression







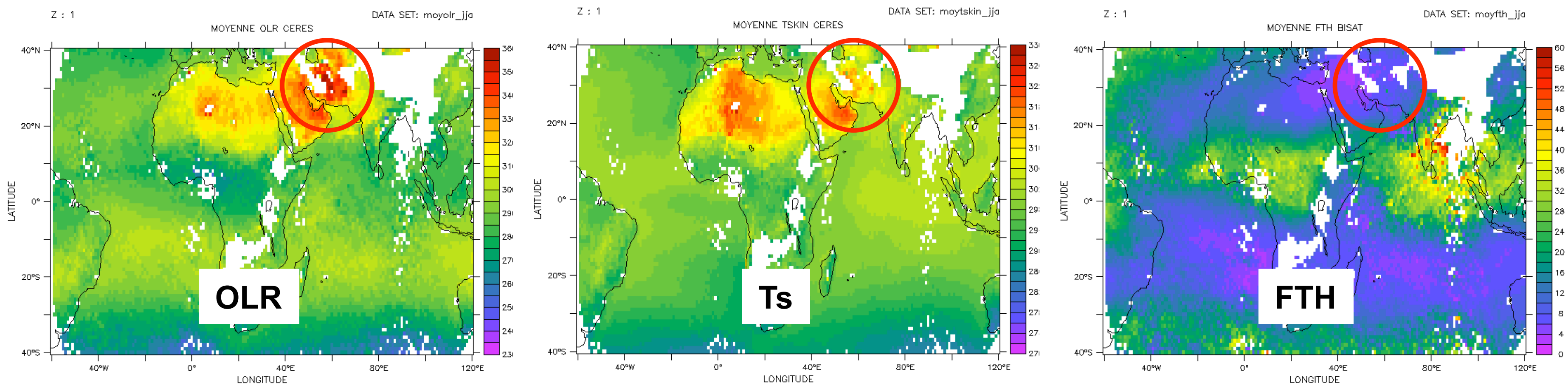
mean OLR_diff (W/m²)



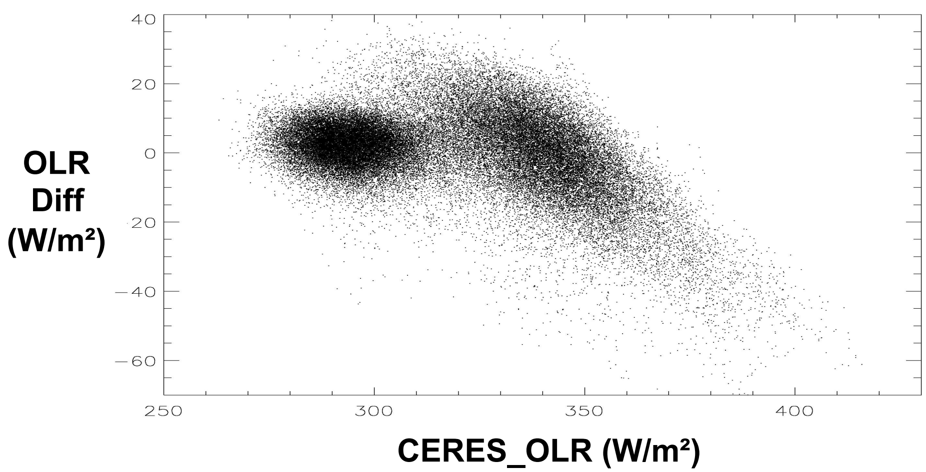
mean OLR_diff (W/m²)

Satellite data (5/6)

III.2 – Multi-linear regression



Mean of the selected data : OLR (left), Ts (centre) and FTH (right).
The highest OLRs do not correspond to the highest temperatures



Problem for the two-parameter model to estimate the highest OLRs (right cluster, day data)

Satellite data (6/6)

III.2 – Multi-linear regression

Correlation coefficients between each variable and the OLR (night)

R : linear correlation coefficient between the FIT and the DATA

Stddev : standard deviation of the FIT-DATA

	Correlation coefficients				
Surface type	$\sigma \cdot T_S{}^4$	$\ln(FTH)$	$\ln(PWAT)$	R^2	$stddev$
Ocean	-0.009	-0.820	-0.540	0.765	4.378
Land	0.572	-0.643	-0.090	0.775	5.816
Desert	0.099	-0.790	0.327	0.693	5.135

The two-parameter model reproduces the OLR with almost the same precision than the vertically and spectrally resolved model

Conclusions

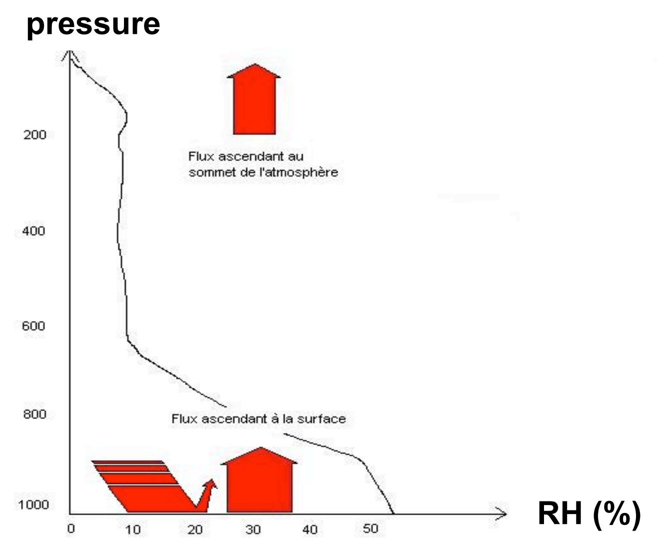
- Surface emissivity has to be taken into account when it is low, particularly in the « window » region

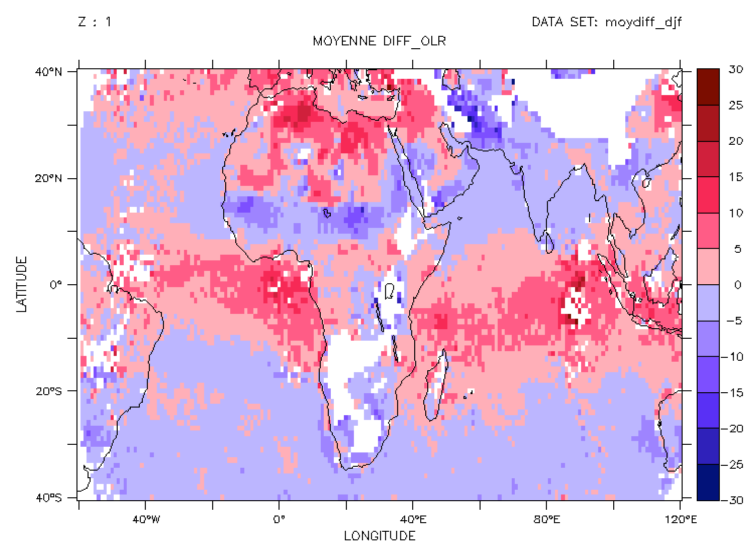
- Systematic errors can reach 10 W/m² and get bigger for higher temperatures, lowest emissivities and drier boundary layers

- The two-parameter statistical model is almost as good as a « complete » vertical and spectral model

Perspectives :

- Identify the reasons of the bias
- Improve the statistical model
- study the variability of OLR and Ga within this statistical model



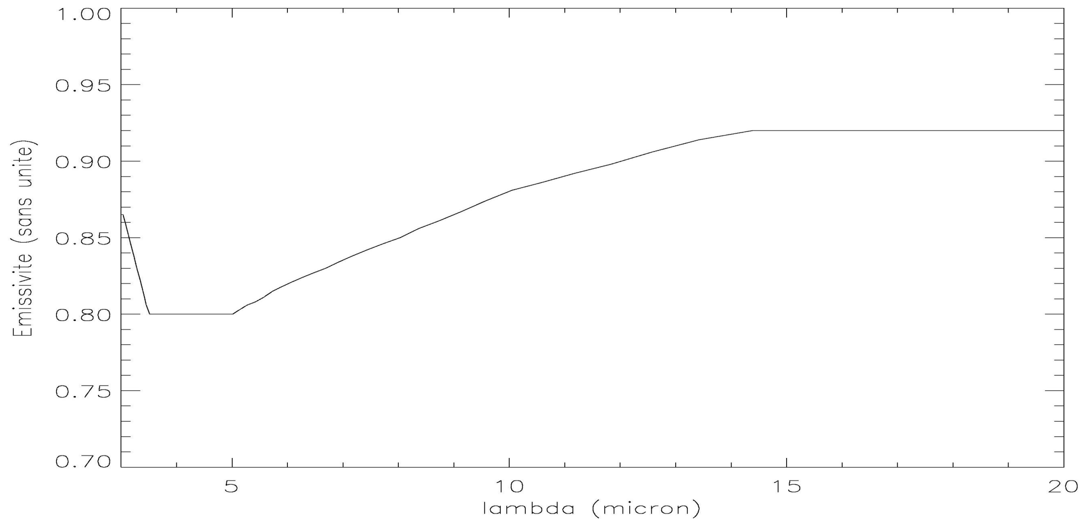


mean OLR_diff (W/m²)

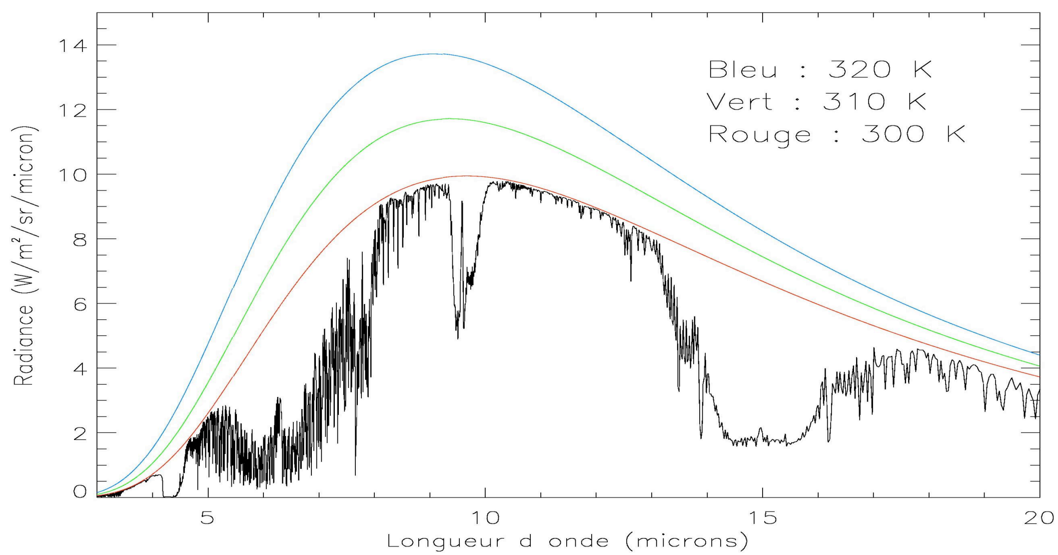
Appendix 1

Modtran

Desertic surface emissivity spectrum from the Modtran model. We highlight the particularly low emissivity values in the atmospheric window, between 8 and 12 µm.



The bulk of the most intense emissions for Ts close to 300 K are in the window part of the spectrum.



Appendix 2

Modtran

Over desert-like emissivity surfaces :

- Ts variations have a major impact on the amount of emission in the atmospheric window

- OLR jacobian becomes positive for RH perturbations in the low layers of the atmosphere

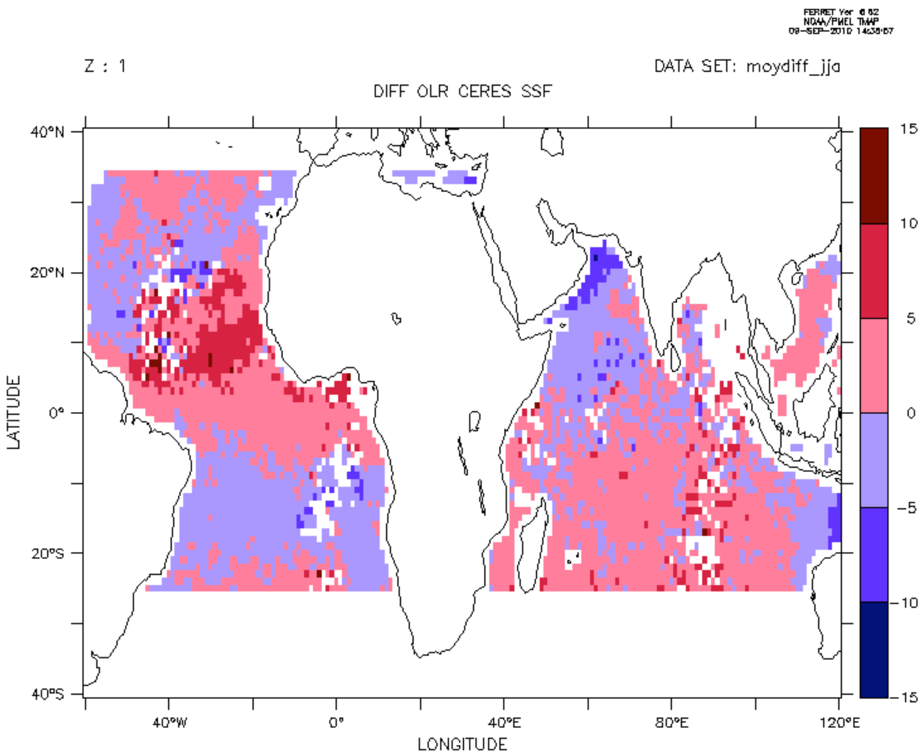
- Emissivity should be taken into acount for low emissivity surfaces, otherwise error of 10 W/m² or more could be done on the OLR estimate

$$LW_{S\uparrow} \approx (1-\varepsilon)\cdot LW_{A\downarrow}(BLH, T_A) + \varepsilon \cdot \sigma \cdot T_S{}^4$$

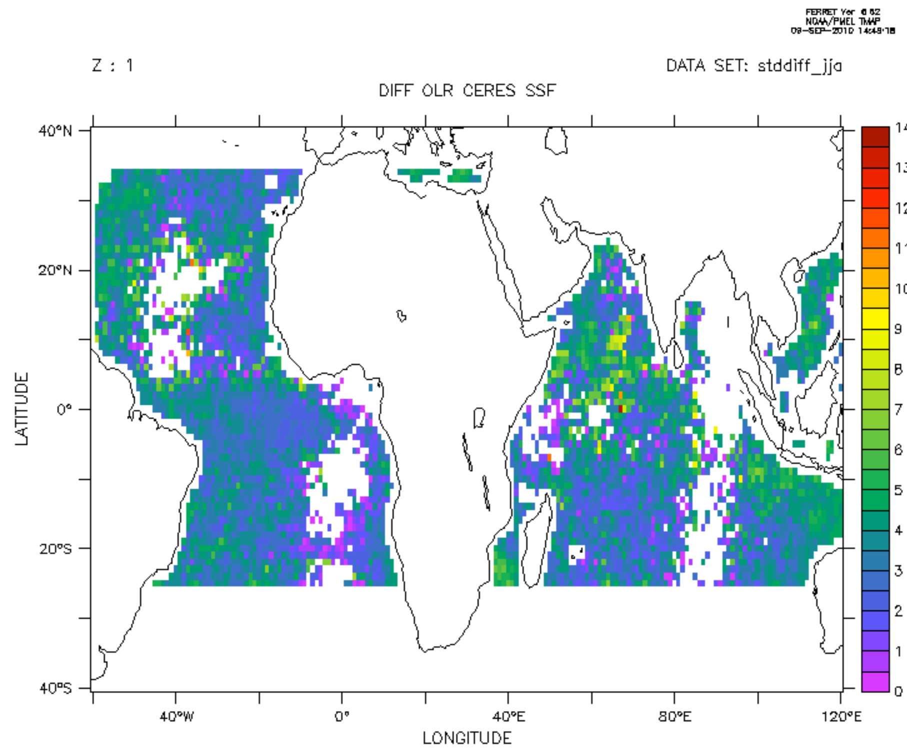
$$OLR \approx f(LW_{S\uparrow}, FTH)$$

Appendix 3

Regression



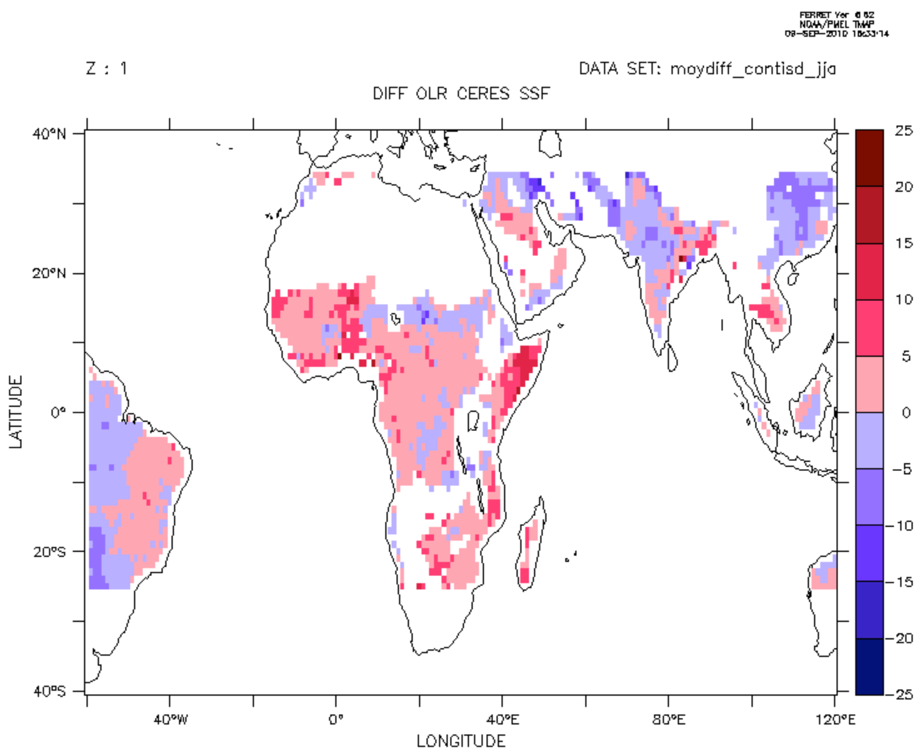
mean OLR_diff (W/m²)



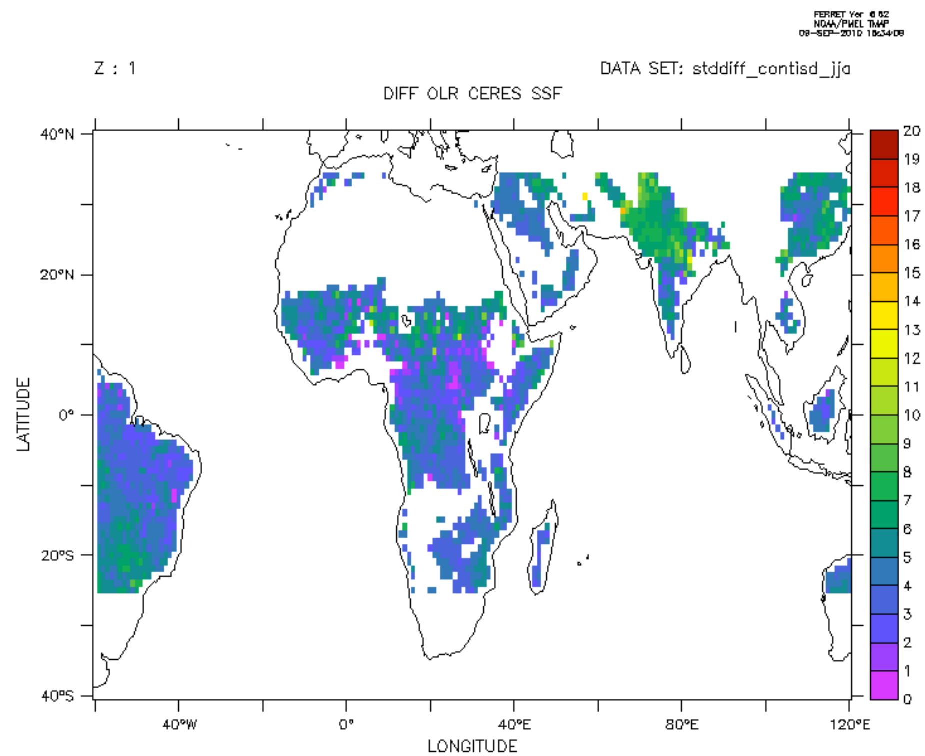
STDDEV

Appendix 4

Regression



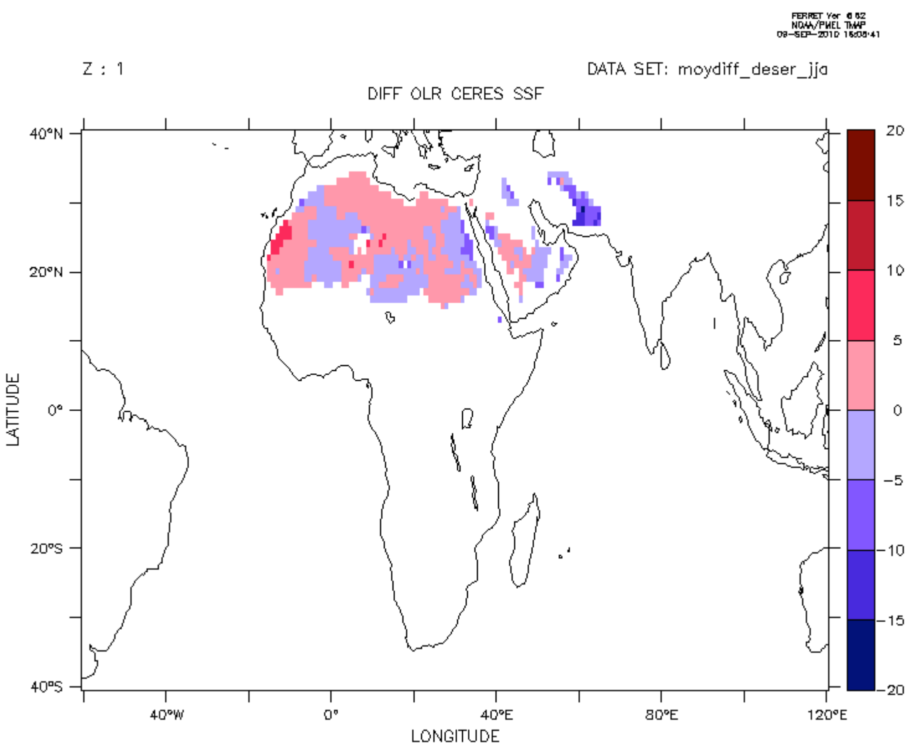
mean OLR_diff (W/m²)



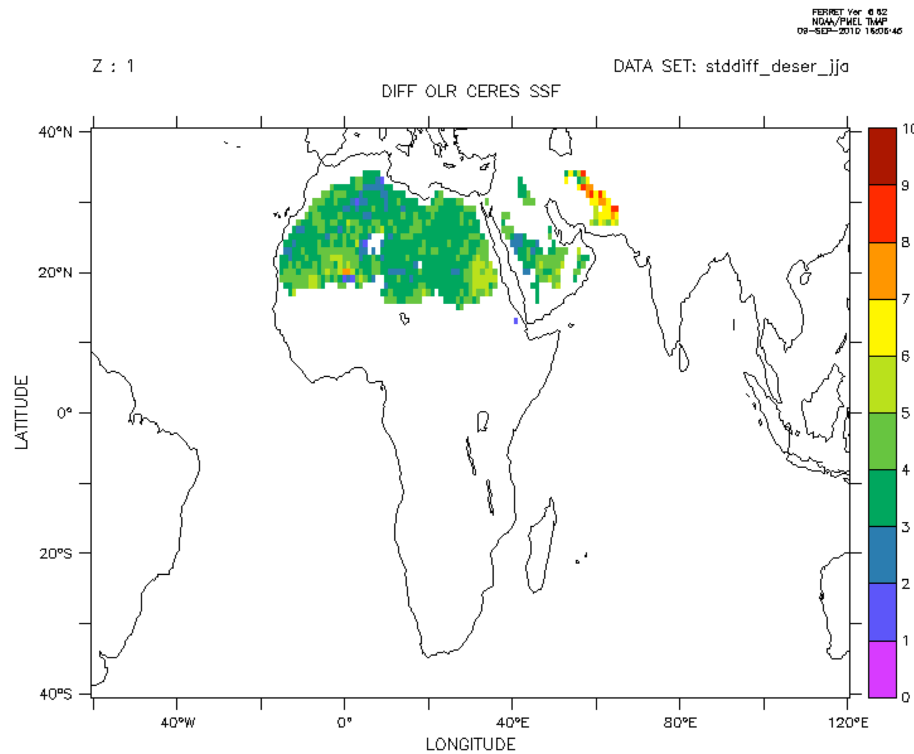
STDDEV

Appendix 5

Regression



mean OLR_diff (W/m²)



STDDEV